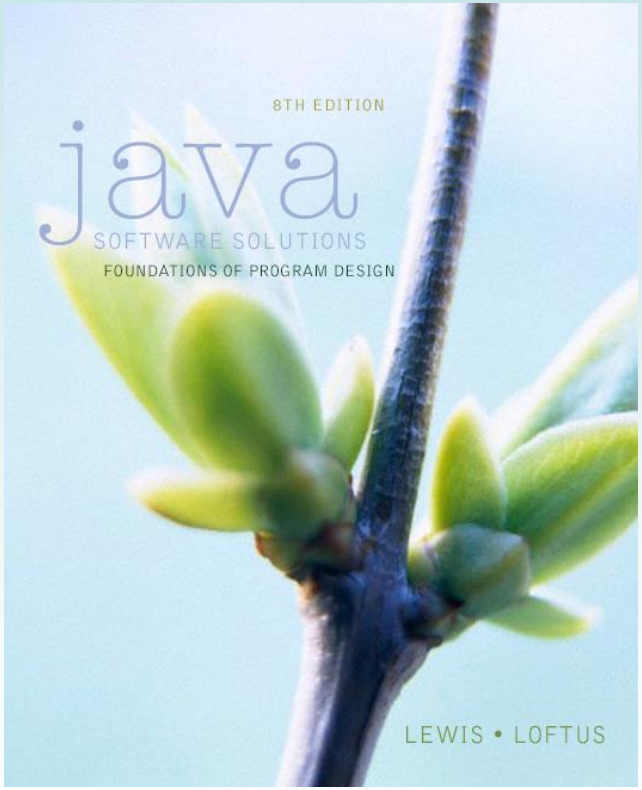
Chapter 2
Data and Expressions



Java Software Solutions

Foundations of Program Design

8th Edition

John Lewis
William Loftus

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Data and Expressions

- Let's explore some other fundamental programming concepts
- Chapter 2 focuses on:
  - character strings
  - primitive data
  - the declaration and use of variables
  - expressions and operator precedence
  - data conversions
  - accepting input from the user
  - Java applets
  - introduction to graphics

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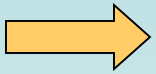
Outline



Character Strings

Variables and Assignment

Primitive Data Types

Expressions

Data Conversion

Interactive Programs

Graphics

Applets

Drawing Shapes

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Character Strings

- A *string literal* is represented by putting double quotes around the text
- Examples:

```
"This is a string literal."
"123 Main Street"
"X"
```

- Every character string is an object in Java, defined by the `String` class
- Every string literal represents a `String` object

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The println Method

- In the `Lincoln` program from Chapter 1, we invoked the `println` method to print a character string
- The `System.out` object represents a destination (the monitor screen) to which we can send output

```
System.out.println ("Whatever you are, be a good one.");
```

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The print Method

- The `System.out` object provides another service as well
- The `print` method is similar to the `println` method, except that it does not advance to the next line
- Therefore anything printed after a `print` statement will appear on the same line
- See `Countdown.java`

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```
//********************************************************************
//  Countdown.java       Author: Lewis/Loftus
//
//  Demonstrates the difference between print and println.
//********************************************************************

public class Countdown
{
   //-----------------------------------------------------------------
   //  Prints two lines of output representing a rocket countdown.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      System.out.print("Three... ");
      System.out.print("Two... ");
      System.out.print("One... ");
      System.out.print("Zero... ");
      System.out.println("Liftoff!");  // appears on first output line
      System.out.println("Houston, we have a problem.");
   }
}
```

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Output

```
Three... Two... One... Zero... Liftoff!
Houston, we have a problem.
```

```
//****                                                              ****
//  Co
//
//  De
//****                                                              ****

public class Countdown
{
   //-----------------------------------------------------------------
   //  Prints two lines of output representing a rocket countdown.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      System.out.print("Three... ");
      System.out.print("Two... ");
      System.out.print("One... ");
      System.out.print("Zero... ");
      System.out.println("Liftoff!");  // appears on first output line
      System.out.println("Houston, we have a problem.");
   }
}
```

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String Concatenation

- The *string concatenation operator* (+) is used to append one string to the end of another

```
"Peanut butter " + "and jelly"
```

- It can also be used to append a number to a string
- A string literal cannot be broken across two lines in a program
- See `Facts.java`

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```
//********************************************************************
//  Facts.java       Author: Lewis/Loftus
//
//  Demonstrates the use of the string concatenation operator and the
//  automatic conversion of an integer to a string.
//********************************************************************

public class Facts
{
   //-----------------------------------------------------------------
   //  Prints various facts.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      // Strings can be concatenated into one long string
      System.out.println("We present the following facts for your "
                         + "extracurricular edification:");

      System.out.println();

      // A string can contain numeric digits
      System.out.println("Letters in the Hawaiian alphabet: 12");
```

continue

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continue

```
        // A numeric value can be concatenated to a string
        System.out.println("Dialing code for Antarctica: " + 672);

        System.out.println("Year in which Leonardo da Vinci invented "
                           + "the parachute: " + 1515);

        System.out.println("Speed of ketchup: " + 40 + " km per year");
    }
}
```

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Output

```
We present the following facts for your extracurricular edification:

Letters in the Hawaiian alphabet: 12
Dialing code for Antarctica: 672
Year in which Leonardo da Vinci invented the parachute: 1515
Speed of ketchup: 40 km per year
```

```
        System.out.println("Speed of ketchup: " + 40 + " km per year");
    }
}
```

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String Concatenation

- The + operator is also used for arithmetic addition
- The function that it performs depends on the type of the information on which it operates
- If both operands are strings, or if one is a string and one is a number, it performs string concatenation
- If both operands are numeric, it adds them
- The + operator is evaluated left to right, but parentheses can be used to force the order
- See `Addition.java`

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```
//********************************************************************
//  Addition.java       Author: Lewis/Loftus
//
//  Demonstrates the difference between the addition and string
//  concatenation operators.
//********************************************************************

public class Addition
{
   //-----------------------------------------------------------------
   //  Concatenates and adds two numbers and prints the results.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      System.out.println("24 and 45 concatenated: " + 24 + 45);

      System.out.println("24 and 45 added: " + (24 + 45));
   }
}
```

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Output

```
24 and 45 concatenated: 2445
24 and 45 added: 69
```

```
//**********                                                    **************
//  Addition.
//
//  Demonstra                                                    string
//  concatena
//*************************************************************************

public class Addition
{
   //-----------------------------------------------------------------
   //  Concatenates and adds two numbers and prints the results.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      System.out.println("24 and 45 concatenated: " + 24 + 45);

      System.out.println("24 and 45 added: " + (24 + 45));
   }
}
```

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Quick Check

What output is produced by the following?

```
System.out.println("X: " + 25);
System.out.println("Y: " + (15 + 50));
System.out.println("Z: " + 300 + 50);
```

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Quick Check

What output is produced by the following?

```
System.out.println("X: " + 25);
System.out.println("Y: " + (15 + 50));
System.out.println("Z: " + 300 + 50);
```

```
X: 25
Y: 65
Z: 30050
```

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Escape Sequences

- What if we wanted to print the quote character?
- The following line would confuse the compiler because it would interpret the second quote as the end of the string

```
System.out.println("I said "Hello" to you.");
```

- An *escape sequence* is a series of characters that represents a special character
- An escape sequence begins with a backslash character (\)

```
System.out.println("I said \"Hello\" to you.");
```

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Escape Sequences

- Some Java escape sequences:

Escape Sequence	Meaning
`\b`	backspace
`\t`	tab
`\n`	newline
`\r`	carriage return
`\"`	double quote
`\'`	single quote
`\\`	backslash

- See `Roses.java`

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```
//********************************************************************
//  Roses.java       Author: Lewis/Loftus
//
//  Demonstrates the use of escape sequences.
//********************************************************************

public class Roses
{
   //-----------------------------------------------------------------
   //  Prints a poem (of sorts) on multiple lines.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      System.out.println("Roses are red,\n\tViolets are blue,\n" +
         "Sugar is sweet,\n\tBut I have \"commitment issues\",\n\t" +
         "So I'd rather just be friends\n\tAt this point in our " +
         "relationship.");
   }
}
```

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Output

```
Roses are red,
      Violets are blue,
Sugar is sweet,
      But I have "commitment issues",
      So I'd rather just be friends
      At this point in our relationship.
```

```
//****
//  Ro
//
//  De
//****

public
{
   //-
   //
   //-----------------------------------------------------------
   public static void main (String[] args)
   {
      System.out.println ("Roses are red,\n\tViolets are blue,\n" +
         "Sugar is sweet,\n\tBut I have \"commitment issues\",\n\t" +
         "So I'd rather just be friends\n\tAt this point in our " +
         "relationship.");
   }
}
```

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Quick Check

Write a single `println` statement that produces the following output:

"Thank you all for coming to my home
tonight," he said mysteriously.

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Quick Check

Write a single `println` statement that produces the following output:

"Thank you all for coming to my home
tonight," he said mysteriously.

```
System.out.println("\"Thank you all for " +
   "coming to my home\ntonight,\" he said " +
   "mysteriously.");
```

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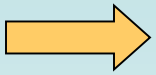
Outline



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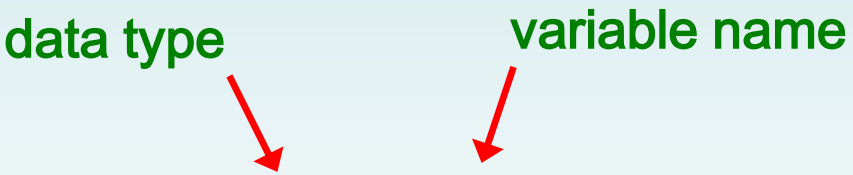
Variables

- A *variable* is a name for a location in memory that holds a value
- A *variable declaration* specifies the variable's name and the type of information that it will hold




```
int total;
int count, temp, result;
```

Multiple variables can be created in one declaration

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Variable Initialization

- A variable can be given an initial value in the declaration

```
int sum = 0;
int base = 32, max = 149;
```

- When a variable is referenced in a program, its current value is used
- See `PianoKeys.java`

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```
//********************************************************************
//  PianoKeys.java       Author: Lewis/Loftus
//
//  Demonstrates the declaration, initialization, and use of an
//  integer variable.
//********************************************************************

public class PianoKeys
{
   //-----------------------------------------------------------------
   //  Prints the number of keys on a piano.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      int keys = 88;
      System.out.println("A piano has " + keys + " keys.");
   }
}
```

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Output

```
A piano has 88 keys.
```

```
//********************************************************************
//  PianoKeys.java
//
//  Demonstrates the declaration, initialization, and use of an
//  integer variable.
//********************************************************************

public class PianoKeys
{
   //-----------------------------------------------------------------
   //  Prints the number of keys on a piano.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      int keys = 88;
      System.out.println("A piano has " + keys + " keys.");
   }
}
```

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Assignment

- An *assignment statement* changes the value of a variable
- The assignment operator is the = sign

```
total = 55;
```

- The value that was in `total` is overwritten
- You can only assign a value to a variable that is consistent with the variable's declared type
- See `Geometry.java`

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```
//********************************************************************
//  Geometry.java       Author: Lewis/Loftus
//
//  Demonstrates the use of an assignment statement to change the
//  value stored in a variable.
//********************************************************************

public class Geometry
{
   //-----------------------------------------------------------------
   //  Prints the number of sides of several geometric shapes.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      int sides = 7;  // declaration with initialization
      System.out.println("A heptagon has " + sides + " sides.");

      sides = 10;  // assignment statement
      System.out.println("A decagon has " + sides + " sides.");

      sides = 12;
      System.out.println("A dodecagon has " + sides + " sides.");
   }
}
```

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Output

```
A heptagon has 7 sides.
A decagon has 10 sides.
a dodecagon has 12 sides.
```

```
//*************                                                  **************
//  Geometry.ja
//
//  Demonstrate                                                 change the
//  value store
//*************                                                  **************

public class Geometry
{
   //-----------------------------------------------------------------
   //  Prints the number of sides of several geometric shapes.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      int sides = 7;  // declaration with initialization
      System.out.println ("A heptagon has " + sides + " sides.");

      sides = 10;  // assignment statement
      System.out.println ("A decagon has " + sides + " sides.");

      sides = 12;
      System.out.println ("A dodecagon has " + sides + " sides.");
   }
}
```

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Constants

- A *constant* is an identifier that is similar to a variable except that it holds the same value during its entire existence
- As the name implies, it is constant, not variable
- The compiler will issue an error if you try to change the value of a constant
- In Java, we use the `final` modifier to declare a constant

```
final int MIN_HEIGHT = 69;
```

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Constants

- Constants are useful for three important reasons
- First, they give meaning to otherwise unclear literal values
  - Example: `MAX_LOAD` means more than the literal 250
- Second, they facilitate program maintenance
  - If a constant is used in multiple places, its value need only be set in one place
- Third, they formally establish that a value should not change, avoiding inadvertent errors by other programmers

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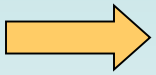
Outline



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Primitive Data

- There are eight primitive data types in Java
- Four of them represent integers:
  - `byte`, `short`, `int`, `long`
- Two of them represent floating point numbers:
  - `float`, `double`
- One of them represents characters:
  - `char`
- And one of them represents boolean values:
  - `boolean`

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Numeric Primitive Data

- The difference between the numeric primitive types is their size and the values they can store:

Type	Storage	Min Value	Max Value
`byte`	8 bits	-128	127
`short`	16 bits	-32,768	32,767
`int`	32 bits	-2,147,483,648	2,147,483,647
`long`	64 bits	$< -9 \times 10^{18}$	$> 9 \times 10^{18}$
`float`	32 bits	$+/- 3.4 \times 10^{38}$ with 7 significant digits	
`double`	64 bits	$+/- 1.7 \times 10^{308}$ with 15 significant digits	

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Characters

- A `char` variable stores a single character
- Character literals are delimited by single quotes:

```
'a'   'X'   '7'   '$'   ','   '\n'
```

- Example declarations:

```
char topGrade = 'A';
char terminator = ';', separator = ' ';
```

- Note the difference between a primitive character variable, which holds only one character, and a `String` object, which can hold multiple characters

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Character Sets

- A *character set* is an ordered list of characters, with each character corresponding to a unique number
- A `char` variable in Java can store any character from the *Unicode character set*
- The Unicode character set uses sixteen bits per character, allowing for 65,536 unique characters
- It is an international character set, containing symbols and characters from many world languages

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Characters

- The *ASCII character set* is older and smaller than Unicode, but is still quite popular

- The ASCII characters are a subset of the Unicode character set, including:

uppercase letters	A, B, C, …
lowercase letters	a, b, c, …
punctuation	period, semi-colon, …
digits	0, 1, 2, …
special symbols	&, |, \, …
control characters	carriage return, tab, ...

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Boolean

- A `boolean` value represents a true or false condition
- The reserved words `true` and `false` are the only valid values for a boolean type

```
boolean done = false;
```

- A `boolean` variable can also be used to represent any two states, such as a light bulb being on or off

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Expressions

- An *expression* is a combination of one or more operators and operands
- *Arithmetic expressions* compute numeric results and make use of the arithmetic operators:

Addition	+
Subtraction	-
Multiplication	*
Division	/
Remainder	%

- If either or both operands are floating point values, then the result is a floating point value

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Division and Remainder

- If both operands to the division operator (/) are integers, the result is an integer (the fractional part is discarded)

```
14 / 3   equals   4
8 / 12   equals   0
```

- The remainder operator (%) returns the remainder after dividing the first operand by the second

```
14 % 3   equals   2
8 % 12   equals   8
```

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Quick Check

What are the results of the following expressions?

```
   12 / 2
12.0 / 2.0
   10 / 4
 10 / 4.0
   4 / 10
 4.0 / 10
   12 % 3
   10 % 3
   3 % 10
```

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Quick Check

What are the results of the following expressions?

```
   12 / 2  =  6
12.0 / 2.0 =  6.0
   10 / 4  =  2
  10 / 4.0 =  2.5
   4 / 10  =  0
  4.0 / 10 =  0.4
   12 % 3  =  0
   10 % 3  =  1
   3 % 10  =  0
```

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Operator Precedence

- Operators can be combined into larger expressions

```
result  =  total + count / max - offset;
```

- Operators have a well-defined precedence which determines the order in which they are evaluated
- Multiplication, division, and remainder are evaluated before addition, subtraction, and string concatenation
- Arithmetic operators with the same precedence are evaluated from left to right, but parentheses can be used to force the evaluation order

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Quick Check

In what order are the operators evaluated in the following expressions?

```
a + b + c + d + e
```

```
a + b * c - d / e
```

```
a / (b + c) - d % e
```

```
a / (b * (c + (d - e)))
```

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Quick Check

In what order are the operators evaluated in the following expressions?

```
a + b + c + d + e
  1   2   3   4
```

```
a + b * c - d / e
  3   1   4   2
```

```
a / (b + c) - d % e
  2    1    4   3
```

```
a / (b * (c + (d - e)))
  4    3    2    1
```

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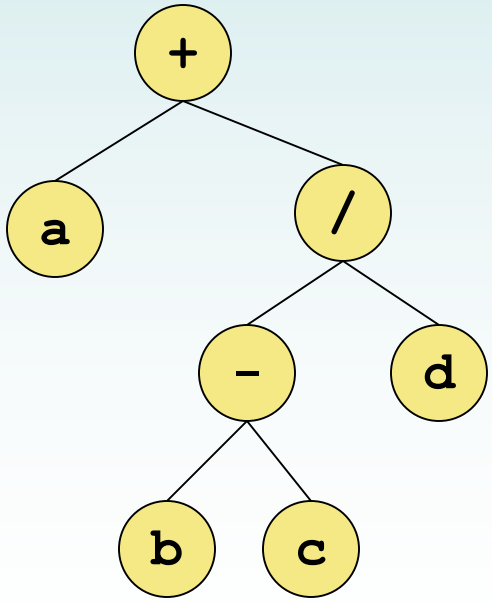
Expression Trees

- The evaluation of a particular expression can be shown using an *expression tree*
- The operators lower in the tree have higher precedence for that expression

```
a + (b - c) / d
```



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Assignment Revisited

- The assignment operator has a lower precedence than the arithmetic operators

First the expression on the right hand side of the = operator is evaluated

```
answer  =  sum / 4 + MAX * lowest;
```

4 1 3 2

Then the result is stored in the variable on the left hand side

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Assignment Revisited

- The right and left hand sides of an assignment statement can contain the same variable

First, one is added to the original value of `count`

```
count  =  count + 1;
```

Then the result is stored back into `count` (overwriting the original value)

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Increment and Decrement

- The increment (++) and decrement (--) operators use only one operand
- The statement

```
count++;
```

  is functionally equivalent to

```
count = count + 1;
```

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Increment and Decrement

- The increment and decrement operators can be applied in *postfix form*:

```
count++
```

- or *prefix form*:

```
++count
```

- When used as part of a larger expression, the two forms can have different effects
- Because of their subtleties, the increment and decrement operators should be used with care

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Assignment Operators

- Often we perform an operation on a variable, and then store the result back into that variable
- Java provides *assignment operators* to simplify that process
- For example, the statement

```
num += count;
```

is equivalent to

```
num = num + count;
```

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Assignment Operators

- There are many assignment operators in Java, including the following:

Operator	Example	Equivalent To
`+=`	`x += y`	`x = x + y`
`-=`	`x -= y`	`x = x - y`
`*=`	`x *= y`	`x = x * y`
`/=`	`x /= y`	`x = x / y`
`%=`	`x %= y`	`x = x % y`

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Assignment Operators

- The right hand side of an assignment operator can be a complex expression
- The entire right-hand expression is evaluated first, then the result is combined with the original variable
- Therefore

```
result /= (total-MIN) % num;
```

is equivalent to

```
result = result / ((total-MIN) % num);
```

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Assignment Operators

- The behavior of some assignment operators depends on the types of the operands
- If the operands to the += operator are strings, the assignment operator performs string concatenation
- The behavior of an assignment operator (+=) is always consistent with the behavior of the corresponding operator (+)

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Data Conversion

- Sometimes it is convenient to convert data from one type to another
- For example, in a particular situation we may want to treat an integer as a floating point value
- These conversions do not change the type of a variable or the value that's stored in it – they only convert a value as part of a computation

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Data Conversion

- *Widening conversions* are safest because they tend to go from a small data type to a larger one (such as a `short` to an `int`)
- *Narrowing conversions* can lose information because they tend to go from a large data type to a smaller one (such as an `int` to a `short`)
- In Java, data conversions can occur in three ways:
  - assignment conversion
  - promotion
  - casting

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Data Conversion

Widening Conversions

From	To
byte	short, int, long, float, or double
short	int, long, float, or double
char	int, long, float, or double
int	long, float, or double
long	float or double
float	double

Narrowing Conversions

From	To
byte	char
short	byte or char
char	byte or short
int	byte, short, or char
long	byte, short, char, or int
float	byte, short, char, int, or long
double	byte, short, char, int, long, or float

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Assignment Conversion

- *Assignment conversion* occurs when a value of one type is assigned to a variable of another
- Example:

```
int dollars = 20;
double money = dollars;
```

- Only widening conversions can happen via assignment
- Note that the value or type of `dollars` did not change

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Promotion

- *Promotion* happens automatically when operators in expressions convert their operands
- Example:

```
int count = 12;
double sum = 490.27;
result = sum / count;
```

- The value of `count` is converted to a floating point value to perform the division calculation

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Casting

- *Casting* is the most powerful, and dangerous, technique for conversion
- Both widening and narrowing conversions can be accomplished by explicitly casting a value
- To cast, the type is put in parentheses in front of the value being converted

```
int total = 50;
float result = (float) total / 6;
```

- Without the cast, the fractional part of the answer would be lost

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Interactive Programs

- Programs generally need input on which to operate
- The `Scanner` class provides convenient methods for reading input values of various types
- A `Scanner` object can be set up to read input from various sources, including the user typing values on the keyboard
- Keyboard input is represented by the `System.in` object

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Reading Input

- The following line creates a `Scanner` object that reads from the keyboard:

```
Scanner scan = new Scanner(System.in);
```

- The `new` operator creates the `Scanner` object
- Once created, the `Scanner` object can be used to invoke various input methods, such as:

```
answer = scan.nextLine();
```

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Reading Input

- The `Scanner` class is part of the `java.util` class library, and must be imported into a program to be used
- The `nextLine` method reads all of the input until the end of the line is found
- See `Echo.java`
- The details of object creation and class libraries are discussed further in Chapter 3

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```
//********************************************************************
//  Echo.java       Author: Lewis/Loftus
//
//  Demonstrates the use of the nextLine method of the Scanner class
//  to read a string from the user.
//********************************************************************

import java.util.Scanner;

public class Echo
{
   //-----------------------------------------------------------------
   //  Reads a character string from the user and prints it.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      String message;
      Scanner scan = new Scanner(System.in);

      System.out.println("Enter a line of text:");

      message = scan.nextLine();

      System.out.println("You entered: \"" + message + "\"");
   }
}
```

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Sample Run

```
Enter a line of text:
You want fries with that?
You entered: "You want fries with that?"
```

```
import java.util.Scanner;

public class Echo
{
   //-----------------------------------------------------------------
   //  Reads a character string from the user and prints it.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      String message;
      Scanner scan = new Scanner(System.in);

      System.out.println("Enter a line of text:");

      message = scan.nextLine();

      System.out.println("You entered: \"" + message + "\"");
   }
}
```

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Input Tokens

- Unless specified otherwise, *white space* is used to separate the elements (called *tokens*) of the input
- White space includes space characters, tabs, new line characters
- The `next` method of the `Scanner` class reads the next input token and returns it as a string
- Methods such as `nextInt` and `nextDouble` read data of particular types
- See `GasMileage.java`

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```
//********************************************************************
//  GasMileage.java       Author: Lewis/Loftus
//
//  Demonstrates the use of the Scanner class to read numeric data.
//********************************************************************

import java.util.Scanner;

public class GasMileage
{
   //-----------------------------------------------------------------
   //  Calculates fuel efficiency based on values entered by the
   //  user.
   //-----------------------------------------------------------------
   public static void main(String[] args)
   {
      int miles;
      double gallons, mpg;

      Scanner scan = new Scanner(System.in);
```

continue

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continue

```
        System.out.print("Enter the number of miles: ");
        miles = scan.nextInt();

        System.out.print("Enter the gallons of fuel used: ");
        gallons = scan.nextDouble();

        mpg = miles / gallons;

        System.out.println("Miles Per Gallon: " + mpg);
    }
}
```

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continue

```
        Sy
        mi

        Sy
        gallons = scan.nextDouble();

        mpg = miles / gallons;

        System.out.println("Miles Per Gallon: " + mpg);
    }
}
```

Sample Run

```
Enter the number of miles: 328
Enter the gallons of fuel used: 11.2
Miles Per Gallon: 29.28571428571429
```

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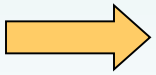

Graphics

Applets

Drawing Shapes

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Introduction to Graphics

- The last few sections of each chapter of the textbook focus on graphics and graphical user interfaces
- A picture or drawing must be digitized for storage on a computer
- A picture is made up of *pixels* (picture elements), and each pixel is stored separately
- The number of pixels used to represent a picture is called the *picture resolution*
- The number of pixels that can be displayed by a monitor is called the *monitor resolution*

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Representing Images

- A digitized picture with a small portion magnified:

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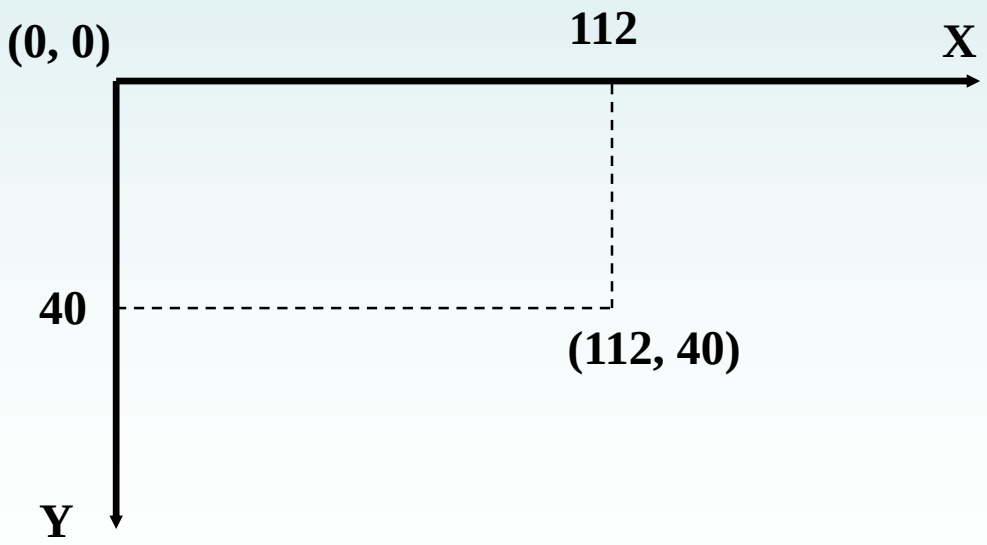
Coordinate Systems

- Each pixel can be identified using a two-dimensional coordinate system
- When referring to a pixel in a Java program, we use a coordinate system with the origin in the top-left corner



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Representing Color

- A black and white picture could be stored using one bit per pixel (0 = white and 1 = black)
- A colored picture requires more information; there are several techniques for representing colors
- Every color can be represented as a mixture of the three additive primary colors Red, Green, and Blue
- Each color is represented by three numbers between 0 and 255 that collectively are called an *RGB value*

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The Color Class

- A color in a Java program is represented as an object created from the `Color` class
- The `Color` class also contains several predefined colors, including the following:

Object	RGB Value
`Color.black`	0, 0, 0
`Color.blue`	0, 0, 255
`Color.cyan`	0, 255, 255
`Color.orange`	255, 200, 0
`Color.white`	255, 255, 255
`Color.yellow`	255, 255, 0

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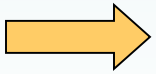

Applets

Drawing Shapes

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Applets

- A Java *application* is a stand-alone program with a `main` method (like the ones we've seen so far)
- A Java *applet* is a program that is intended to be transported over the Web and executed using a web browser
- An applet also can be executed using the appletviewer tool of the Java SDK
- An applet doesn't have a `main` method
- Instead, there are several special methods that serve specific purposes

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Applets

- The `paint` method is executed automatically whenever the applet's contents are drawn
- The `paint` method accepts a parameter that is an object of the `Graphics` class
- A `Graphics` object defines a *graphics context* on which we can draw shapes and text
- The `Graphics` class has several methods for drawing shapes

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Applets

- We create an applet by *extending* the `JApplet` class
- The `JApplet` class is part of the `javax.swing` package
- This makes use of *inheritance*, which is explored in more detail in Chapter 8
- See `Einstein.java`

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```
//********************************************************************
//  Einstein.java       Author: Lewis/Loftus
//
//  Demonstrates a basic applet.
//********************************************************************

import javax.swing.JApplet;
import java.awt.*;

public class Einstein extends JApplet
{
   //-----------------------------------------------------------------
   //  Draws a quotation by Albert Einstein among some shapes.
   //-----------------------------------------------------------------
   public void paint(Graphics page)
   {
      page.drawRect(50, 50, 40, 40);     // square
      page.drawRect(60, 80, 225, 30);    // rectangle
      page.drawOval(75, 65, 20, 20);     // circle
      page.drawLine(35, 60, 100, 120);   // line

      page.drawString("Out of clutter, find simplicity.", 110, 70);
      page.drawString("-- Albert Einstein", 130, 100);
   }
}
```

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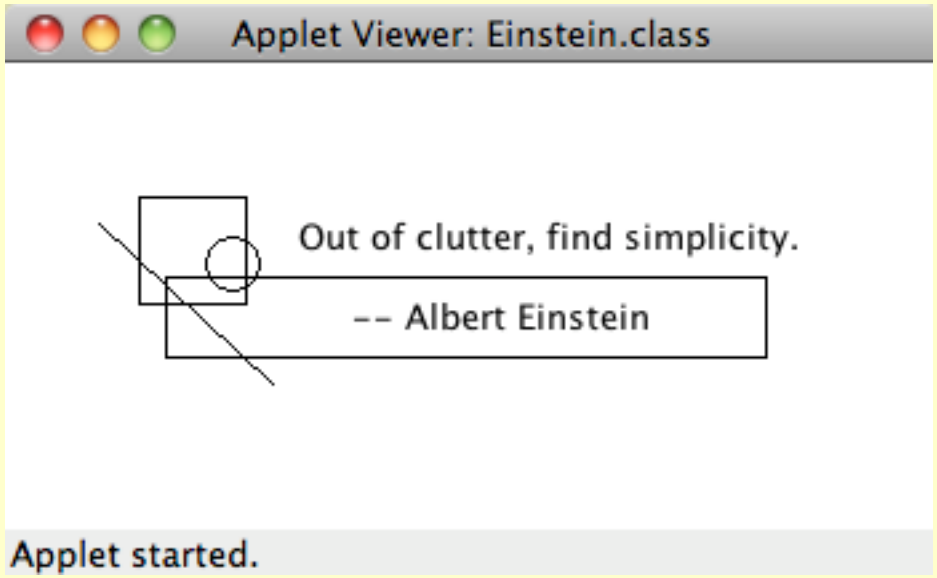
```
//*********                                                    **********
//  Einstei
//
//  Demonst
//*********                                                    **********

import java
import java

public clas
{
   //------                                                   ----------
   //  Draw                                                   s.
   //------                                                   ----------
   public v
   {
      page.drawRect(50, 50, 40, 40);     // square
      page.drawRect(60, 80, 225, 30);    // rectangle
      page.drawOval(75, 65, 20, 20);     // circle
      page.drawLine(35, 60, 100, 120);   // line

      page.drawString("Out of clutter, find simplicity.", 110, 70);
      page.drawString("-- Albert Einstein", 130, 100);
   }
}
```



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The HTML applet Tag

- An applet is embedded into an HTML file using a tag that references the bytecode file of the applet
- The bytecode version of the program is transported across the web and executed by a Java interpreter that is part of the browser

```
<html>
   <head>
      <title>The Einstein Applet</title>
   </head>
   <body>
      <applet code="Einstein.class" width=350 height=175>
      </applet>
   </body>
</html>
```

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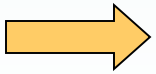

Drawing Shapes

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Drawing Shapes

- Let's explore some of the methods of the `Graphics` class that draw shapes in more detail
- A shape can be filled or unfilled, depending on which method is invoked
- The method parameters specify coordinates and sizes
- Shapes with curves, like an oval, are usually drawn by specifying the shape's *bounding rectangle*
- An arc can be thought of as a section of an oval

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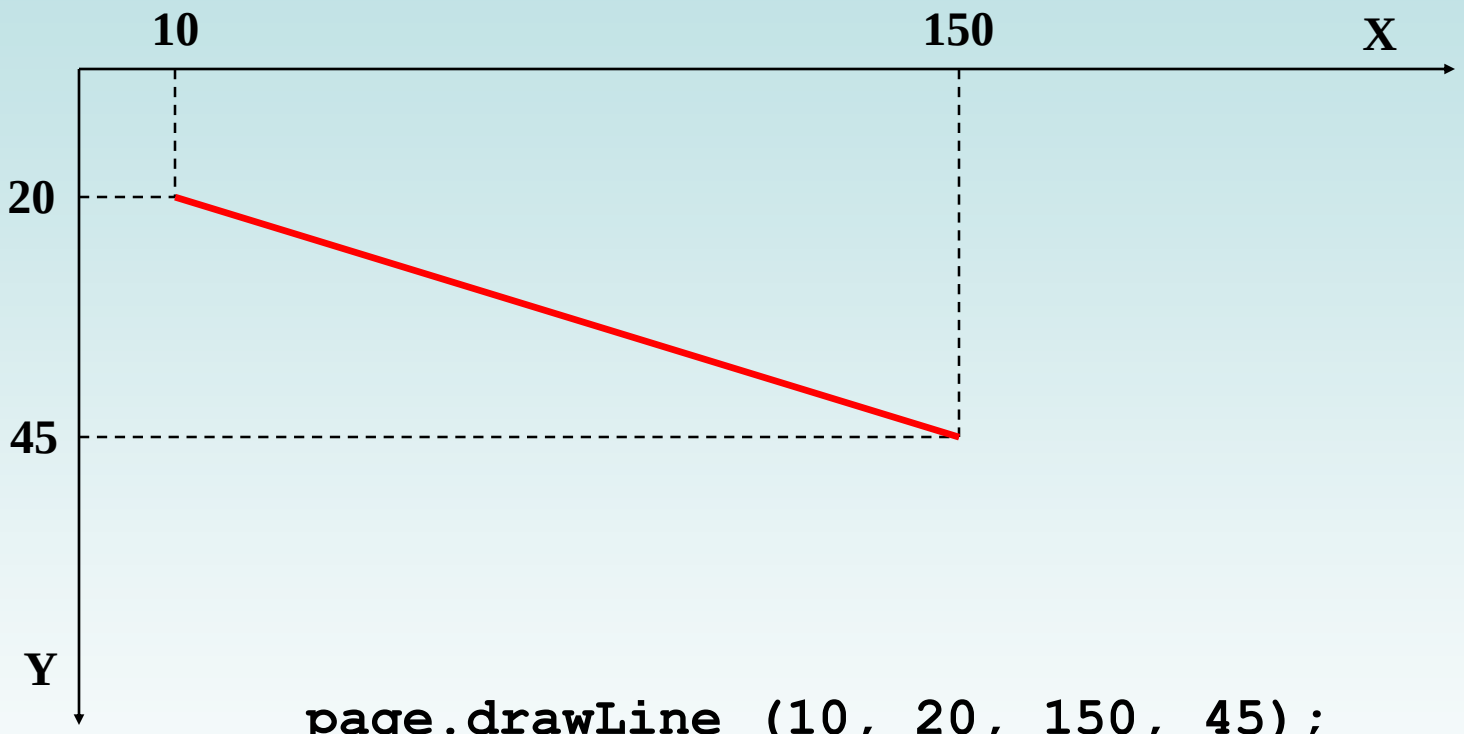
Drawing a Line




```
page.drawLine (10, 20, 150, 45);
```

or

```
page.drawLine (150, 45, 10, 20);
```

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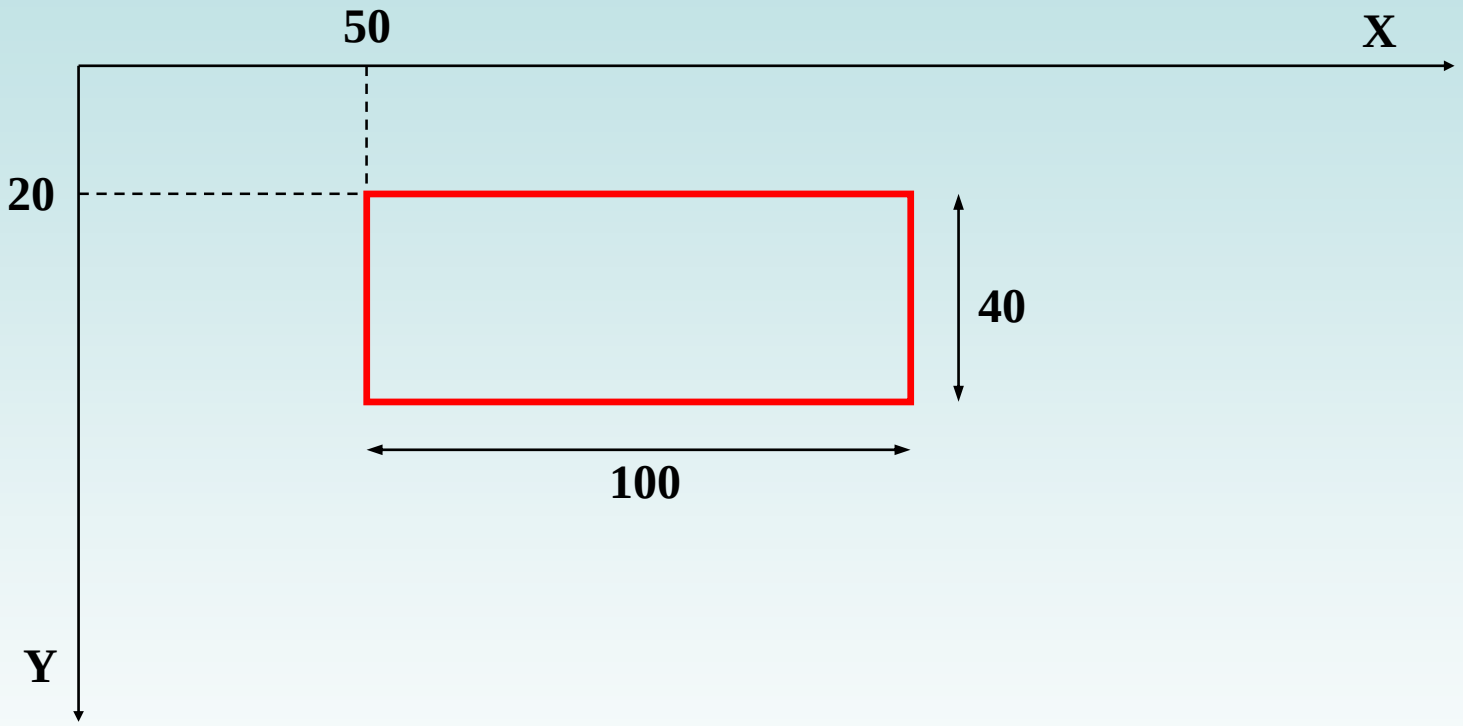
Drawing a Rectangle




```
page.drawRect (50, 20, 100, 40);
```

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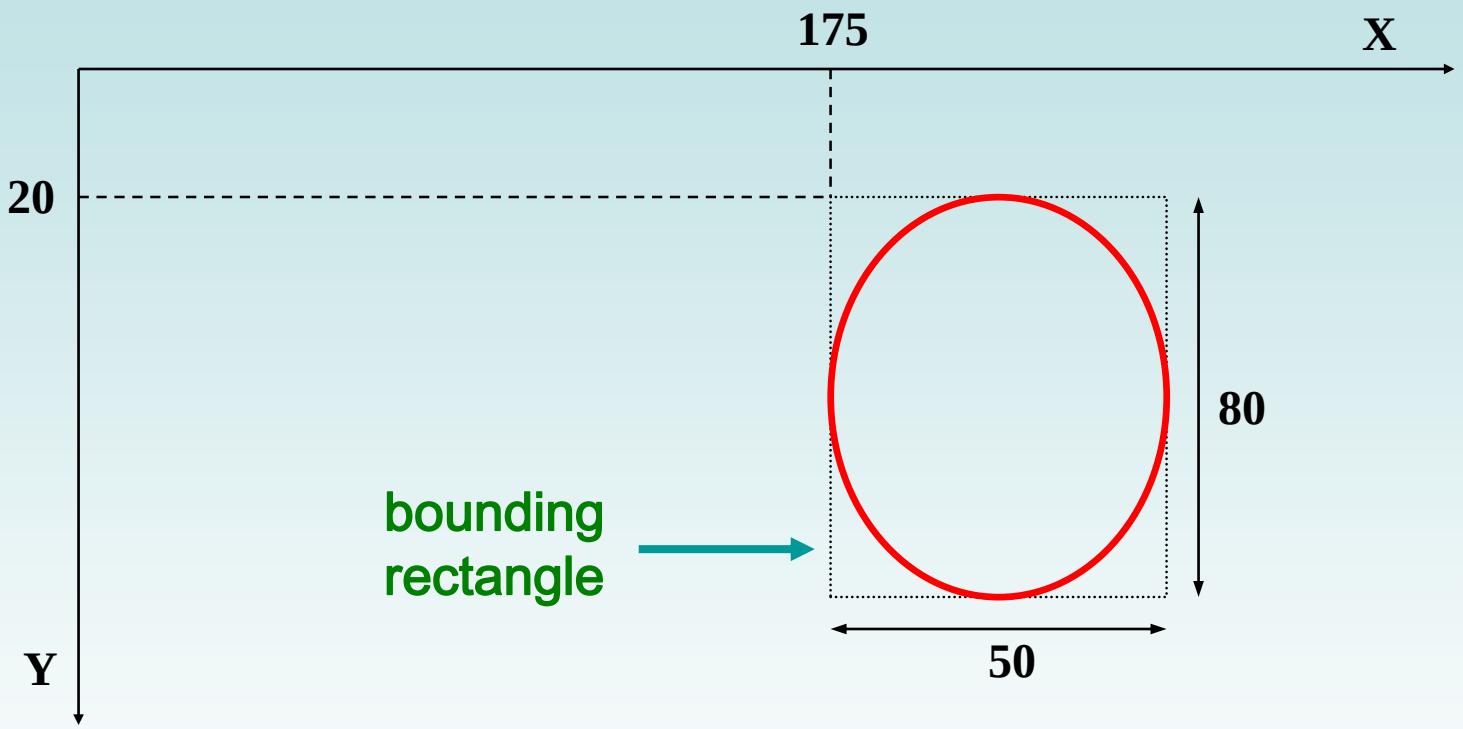
Drawing an Oval




```
page.drawOval (175, 20, 50, 80);
```

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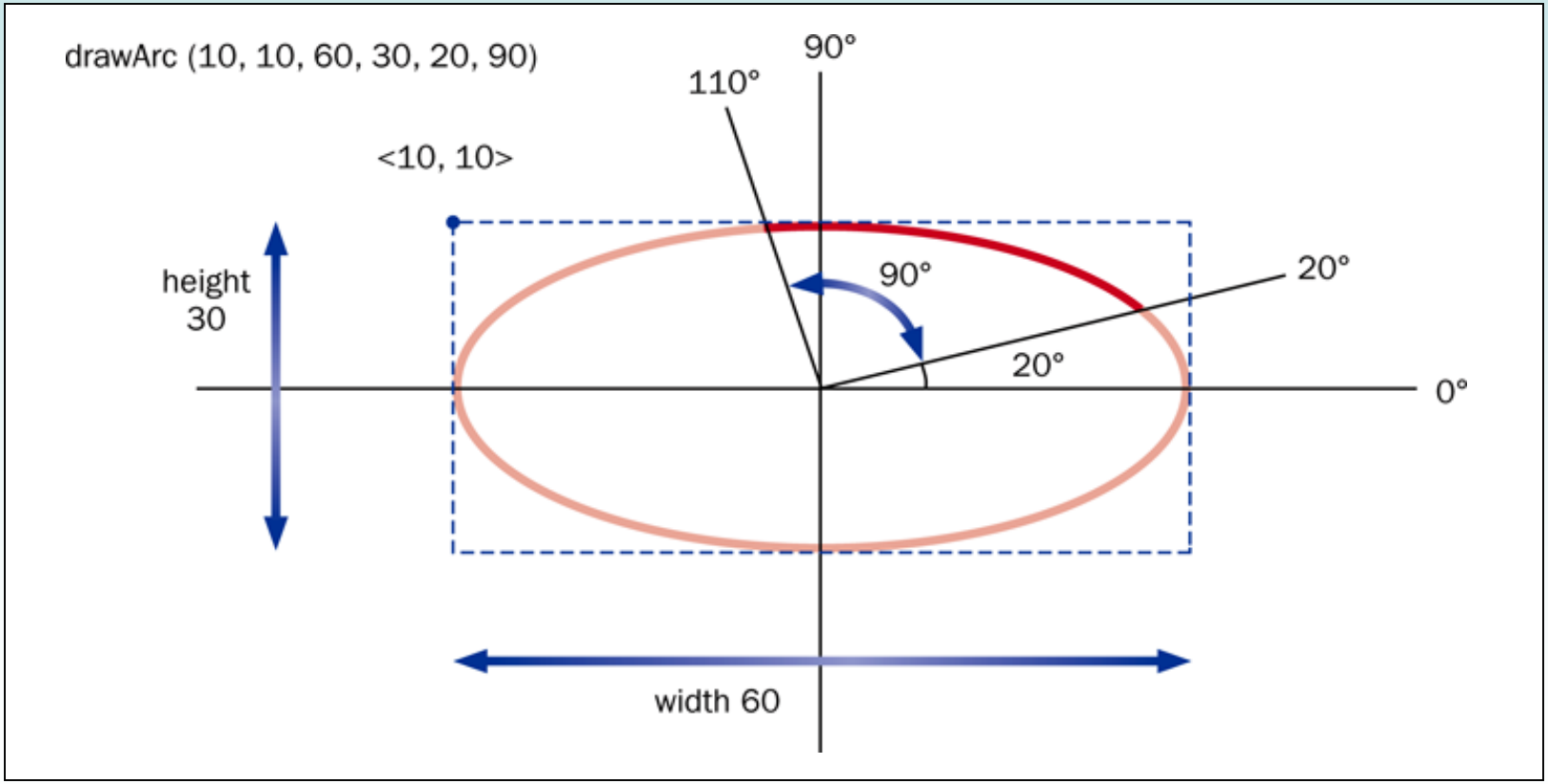
Drawing an Arc

- An arc is defined by an oval, a start angle, and an arc angle:



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Drawing Shapes

- Every drawing surface has a *background color*
- Every graphics context has a current *foreground color*
- Both can be set explicitly
- See `Snowman.java`

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```
//********************************************************************
//  Snowman.java       Author: Lewis/Loftus
//
//  Demonstrates basic drawing methods and the use of color.
//********************************************************************

import javax.swing.JApplet;
import java.awt.*;

public class Snowman extends JApplet
{
   //-----------------------------------------------------------------
   //  Draws a snowman.
   //-----------------------------------------------------------------
   public void paint(Graphics page)
   {
      final int MID = 150;
      final int TOP = 50;

      setBackground(Color.cyan);

      page.setColor(Color.blue);
      page.fillRect(0, 175, 300, 50);  // ground

      page.setColor(Color.yellow);
      page.fillOval(-40, -40, 80, 80);  // sun
```

continued

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continued

```
        page.setColor(Color.white);
        page.fillOval(MID-20, TOP, 40, 40);       // head
        page.fillOval(MID-35, TOP+35, 70, 50);    // upper torso
        page.fillOval(MID-50, TOP+80, 100, 60);   // lower torso

        page.setColor(Color.black);
        page.fillOval(MID-10, TOP+10, 5, 5);    // left eye
        page.fillOval(MID+5, TOP+10, 5, 5);     // right eye

        page.drawArc(MID-10, TOP+20, 20, 10, 190, 160);   // smile

        page.drawLine(MID-25, TOP+60, MID-50, TOP+40);  // left arm
        page.drawLine(MID+25, TOP+60, MID+55, TOP+60);  // right arm

        page.drawLine(MID-20, TOP+5, MID+20, TOP+5);  // brim of hat
        page.fillRect(MID-15, TOP-20, 30, 25);        // top of hat
    }
}
```

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continued

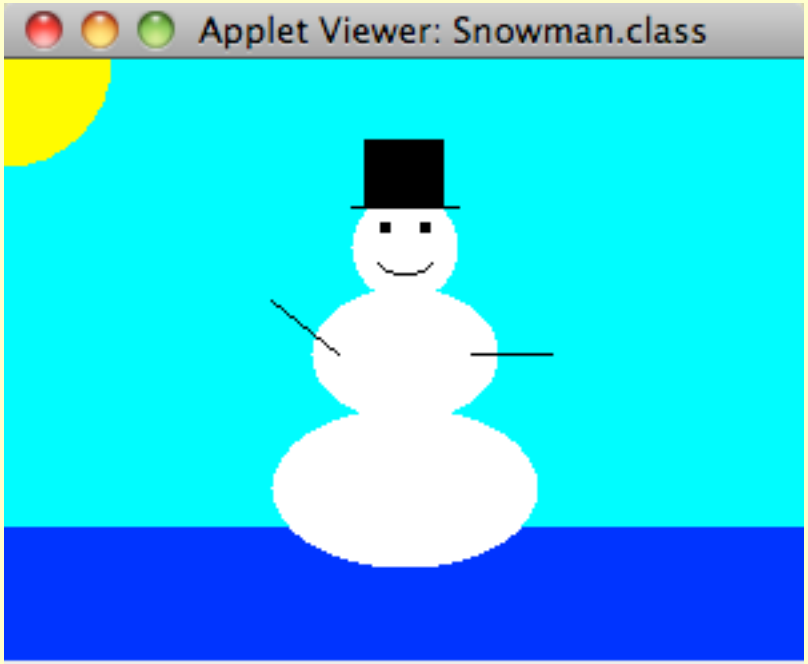
```
        page.se
        page.fi
        page.fi                                                    rso
        page.fi                                                    rso

        page.se
        page.fi
        page.fi

        page.dr                                                     smile

        page.dr                                                    eft arm
        page.dr                                                    ight arm

        page.dr                                                    m of hat
        page.fillRect(MID-15, TOP-20, 30, 25);          // top of hat
    }
}
```



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Summary

- Chapter 2 focused on:
  - character strings
  - primitive data
  - the declaration and use of variables
  - expressions and operator precedence
  - data conversions
  - accepting input from the user
  - Java applets
  - introduction to graphics

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